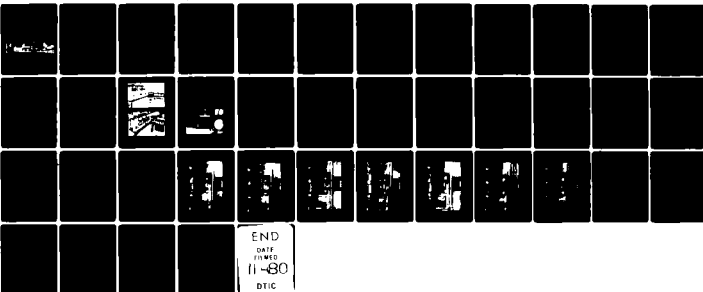


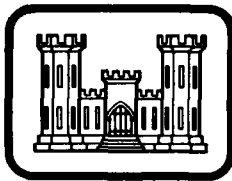
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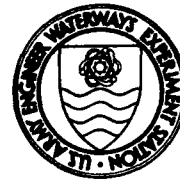
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TECHNICAL REPORT HL-80-19

MCMILLAN PUMPING STATION WASHINGTON, D. C.

Hydraulic Model Investigation

by

Glenn R. Triplett

Hydraulics Laboratory

U. S. Army Engineer Waterways Experiment Station
P. O. Box 631, Vicksburg, Miss. 39180

September 1980

Final Report

Approved For Public Release; Distribution Unlimited

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Prepared for U. S. Army Engineer District, Baltimore
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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER Technical Report HL-80-19	2. GOVT ACCESSION NO. AD-A090276	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) McMILLAN PUMPING STATION, WASHINGTON, D. C.; Hydraulic Model Investigation.	5. TYPE OF REPORT & PERIOD COVERED Final report. 77- 77.	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Glenn R. Triplett	8. CONTRACT OR GRANT NUMBER(s)	
9. PERFORMING ORGANIZATION NAME AND ADDRESS U. S. Army Engineer Waterways Experiment Station Hydraulics Laboratory P. O. Box 631, Vicksburg, Miss. 39180	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS	
11. CONTROLLING OFFICE NAME AND ADDRESS U. S. Army Engineer District, Baltimore P. O. Box 1715 Baltimore, Md. 21203	12. REPORT DATE September 1980	13. NUMBER OF PAGES 40
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) (12) 47	15. SECURITY CLASS. (of this report) Unclassified	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Baffles Pump intakes Flow distribution Pumping stations Hydraulic models Sumps McMillan Pumping Station		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This model study was conducted to evaluate the characteristics of inflow conditions into an existing pump sump that would result with increased discharge capacity due to installation of the three proposed pumps and to develop modifications, if needed, within the confines of the present sump to improve flow distribution to the pump intakes. The operation of the 1:9.6-scale model of the original design sump (Continued)		

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20. ABSTRACT (Continued).

indicated vortexing, turbulence, and severe rotational flow conditions (swirl) caused by uneven flow distribution in the proximity of the pump intakes. Improved inflow distribution to the pump intakes was obtained by installing baffles to divert the concentrated inflow away from the pump intakes. Stilling well type baffles, the most effective modification, diverted concentrated inflow upward and away from the pump intake, dissipated some of the excessive kinetic energy of inflow, and essentially eliminated adverse effects of secondary crossflow. Determining the appropriate bell distance from the sump floor also contributed to improve flow distribution to the pump intakes.

With the modifications developed, flow conditions were improved, vortices were eliminated, and swirl and pressure fluctuations were reduced substantially. Results were satisfactory for all anticipated water-surface elevations and combinations of pumps operating.

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PREFACE

The model investigation reported herein was authorized by the Office, Chief of Engineers (OCE), U. S. Army, on 15 Dec 1977 at the request of the U. S. Army Engineer Division, North Atlantic, and the U. S. Army Engineer District, Baltimore.

The study was conducted during the period December 1977 to January 1979 in the Hydraulics Laboratory of the U. S. Army Engineer Waterways Experiment Station (WES) under the direction of Messrs. H. B. Simmons, Chief of the Hydraulics Laboratory, and J. L. Grace, Jr., Chief of the Hydraulic Structures Division, and under the direct supervision of Mr. N. R. Oswalt, Chief of the Spillways and Channels Branch. The engineer in immediate charge of the model was Mr. G. R. Triplett, assisted by Mr. B. Perkins. This report was prepared by Mr. Triplett.

Commanders and Directors of WES during the conduct of the tests and the preparation and publication of this report were COL John L. Cannon, CE, and COL Nelson P. Conover, CE. Technical Director was Mr. F. R. Brown.

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CONTENTS

	<u>Page</u>
PREFACE	1
CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI)	
UNITS OF MEASUREMENT	3
PART I: INTRODUCTION	5
The Prototype	5
Purpose of Model Study	10
PART II: THE MODEL	12
Description	12
Interpretation of Model Results	15
PART III: TESTS AND RESULTS	16
Original Design	16
Experimental Designs	16
Recommended Design	20
PART IV: CONCLUSIONS	22
TABLES 1 and 2	
PHOTOS 1-7	
PLATES 1-6	

CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI)
UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

<u>Multiply</u>	<u>By</u>	<u>To Obtain</u>
feet	0.3048	metres
gallons per minute	3.785412	cubic decimetres per minute
gallons (U. S. liquid)	3.785412	cubic decimetres
inches	25.4	millimetres
miles (U. S. statute)	1.609344	kilometres

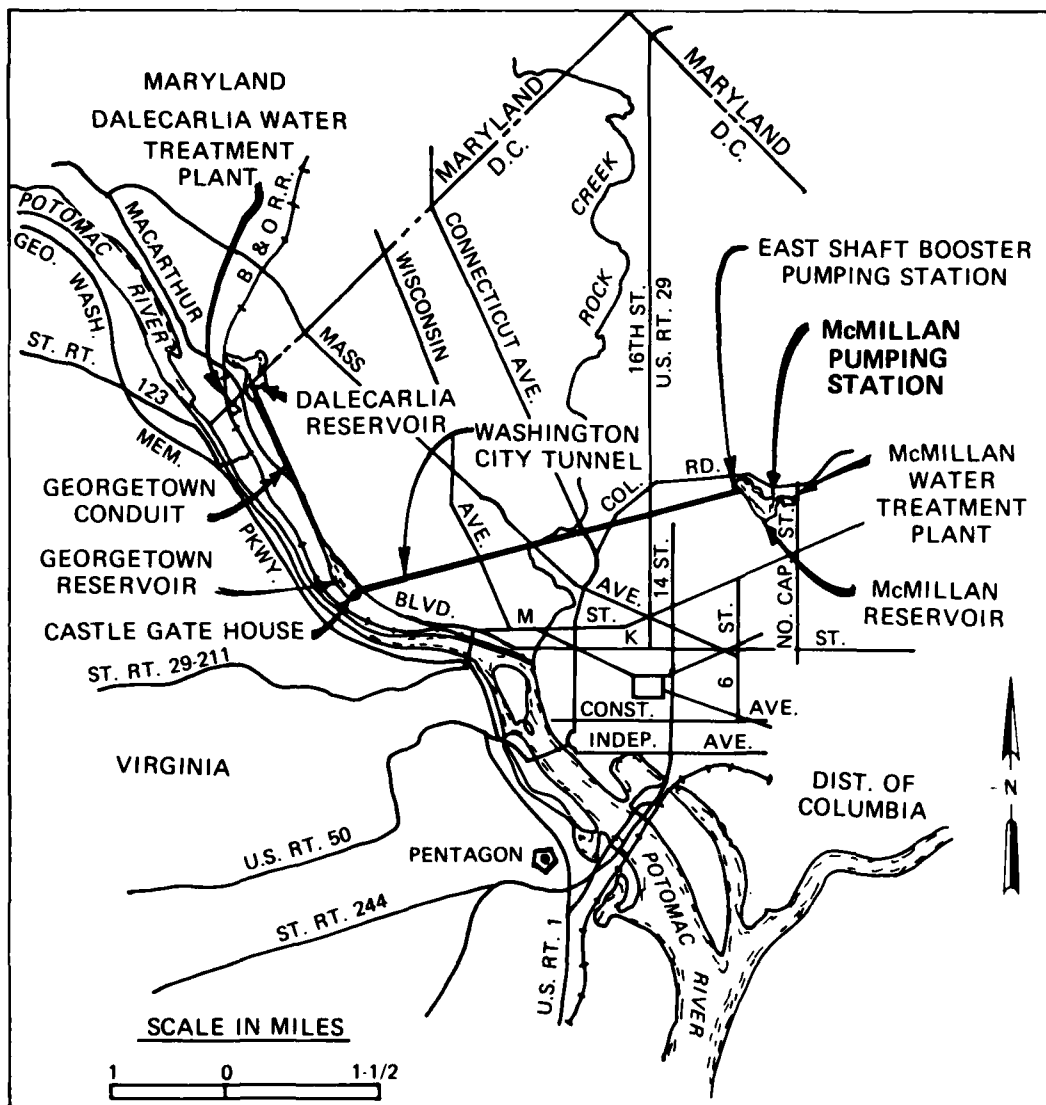


Figure 1. Location map

McMILLAN PUMPING STATION, WASHINGTON, D. C.

Hydraulic Model Investigation

PART I: INTRODUCTION

The Prototype

1. The McMillan Pumping Station, a part of the water supply system which serves Washington, D. C., and northern Virginia (Figure 1), gets its water from the McMillan Reservoir and pumps it into the McMillan Water Treatment Plant (Plates 1 and 2). Improvements are planned that will increase nominal plant capacity of the McMillan Treatment Plant from 100 to 120 mgd.* This makes it necessary to increase the capacity of each of the three pumps of the McMillan Pumping Station from 60 to 90 mgd. The desired capacity of each pump is about one half of the capacity required of the McMillan Water Treatment Plant about 90 percent of the time.

2. The McMillan Pumping Station, located at the south end of Filter Court No. 1 on McMillan Drive, is approximately 70 ft north of McMillan Reservoir and 300 ft southwest of the proposed McMillan Filter and Chemical Building. Construction of the McMillan Pumping Station, intake structure, and appurtenant piping connections was completed about 1903. Since construction, two major alterations have been made. In 1945, the original pumping equipment was replaced by axial flow, adjustable vane pumps. In 1948, self-cleaning screens were added to the intake structure. The proposed modification to change the pumps will not change the wet-well sump.

3. The McMillan Reservoir and the East Shaft Booster Pumping Station receive gravity-flow water from the Georgetown Reservoir through the 4-mile Washington City Tunnel. The Washington City Tunnel is approximately 9 ft in diameter through rock. The maximum capacity with gravity

* A table of factors for converting metric (SI) units of measurement to U. S. customary units is presented on page 3.

flow is 90 to 100 mgd with the Georgetown Reservoir at el 144-145* and the McMillan Reservoir drawn down to el 139. From the top of the East Shaft the water flows through five parallel conduits in the old gate chamber and then through 1600 ft of 9.33-ft-diam concrete pipe to the far side of the McMillan Reservoir. The 1600-ft concrete pipe is known as the circulating conduit. The Georgetown Reservoir, as well as the Dalecarlia Water Treatment Plant, receives gravity-flow water from the Dalecarlia Reservoir. The hydraulic profile shown in Figures 2 and 3 shows the flow pattern more clearly.

4. Settled water flows into the wet-well sump at the McMillan Pumping Station through four 48-in. cast iron pipes. These pipes are supplied from a common 6- x 25-ft channel inside the existing intake structure located on the shoreline of the McMillan Reservoir. Each 48-in. pipe has an isolation sluice gate located at the pipe inlet inside the channel. The wet well is divided into three compartments with one pump at the approximate center of each (Figure 4). Each compartment is supplied by at least one of the four 48-in. pipes that deliver settled water to the pumping station from the intake structure. Stop logs are available that can be used to isolate each compartment. This allows any one of the pumps to be taken out of service and the wet-well compartment to be dewatered without stopping operation of the remaining pumps. The overall dimensions of the wet well are approximately 13 x 70 ft; it is of groined-arch construction with a low point at the bottom at el 123.67. Submergence requirements of the new pumps limit the minimum sump water level to el 139. Anticipated high sump water level is el 146.

5. Each of the three proposed pumps for McMillan Pumping Station will have a rated capacity of 62,500 gpm at a head of 47 ft. They will be vertical, axial-flow type pumps equipped with 100-hp synchronous motors and magnetic coupling variable speed drives. Design considerations of the proposed pumps were coordinated with gravity-flow capabilities of the Washington City Tunnel and the East Shaft, and the required water-surface elevation in the McMillan Reservoir (Figure 2).

* All elevations (el) cited herein are in feet referred to mean sea level.

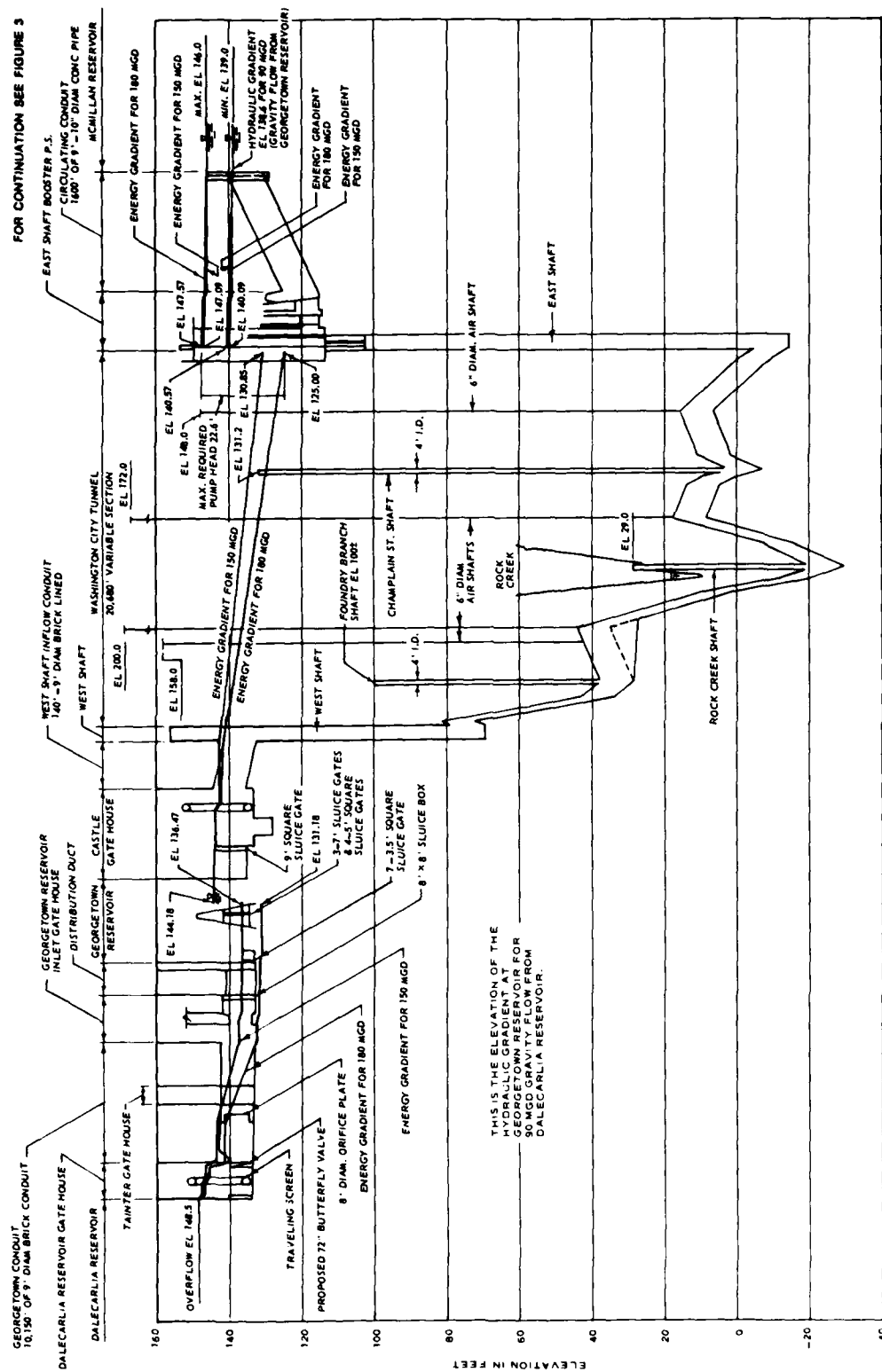
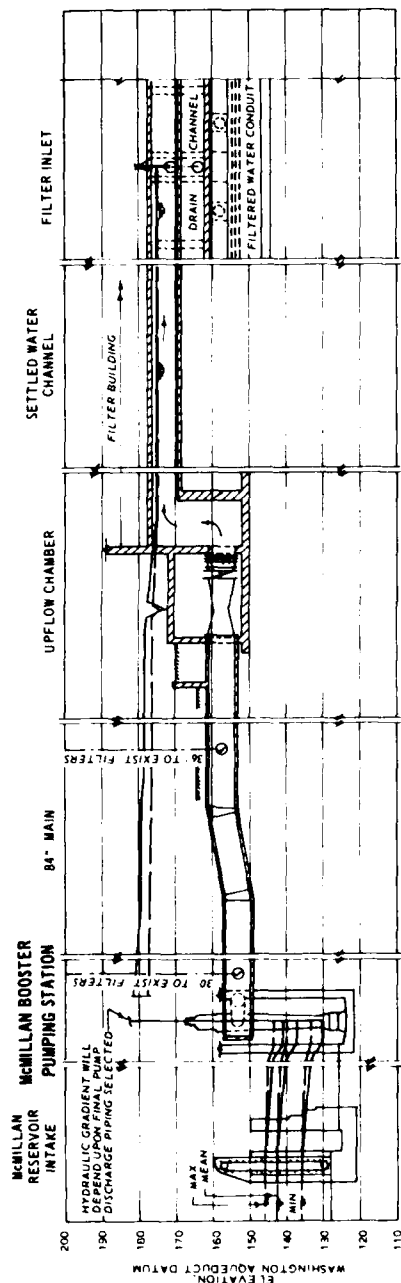
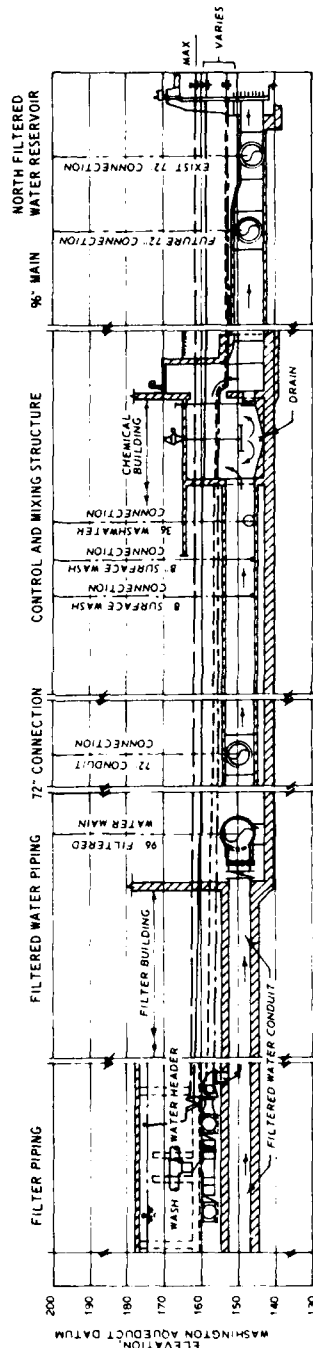


Figure 2. Hydraulic profile, Dalecarlia Reservoir to McMillan Reservoir

FOR CONTINUATION SEE FIGURE 2



SETTLED WATER HYDRAULIC GRADIENTS



FILTERED WATER HYDRAULIC GRADIENTS

LEGEND

- HYDRAULIC GRADIENT, 120 MGD, RESERVOIR IN CONTROL (SEE NOTE 1)
- HYDRAULIC GRADIENT, 180 MGD, RESERVOIR IN CONTROL (SEE NOTE 1)
- HYDRAULIC GRADIENT, 120 MGD, WEIR IN CONTROL (SEE NOTE 2)
- HYDRAULIC GRADIENT, 180 MGD, WEIR IN CONTROL (SEE NOTE 2)

NOTE: RESERVOIR IN CONTROL - REFERENCE ELEVATION IS THE MAXIMUM POSSIBLE ELEVATION OF THE WEIR CREST. WEIR LEVEL FOR THE FLOW RATE SHOWN.
WEIR IN CONTROL - REFERENCE ELEVATION IS THE FREE FALL ELEVATION OVER THE WEIR CREST FOR THE FLOW RATE SHOWN. THE WEIR CREST IS THE LEVEL JUST DOWNSTREAM FROM THE WEIR CREST, OR BELOW THE WEIR CREST.

Figure 3. Hydraulic profile, McMillan Reservoir through proposed rapid sand filter water treatment plant

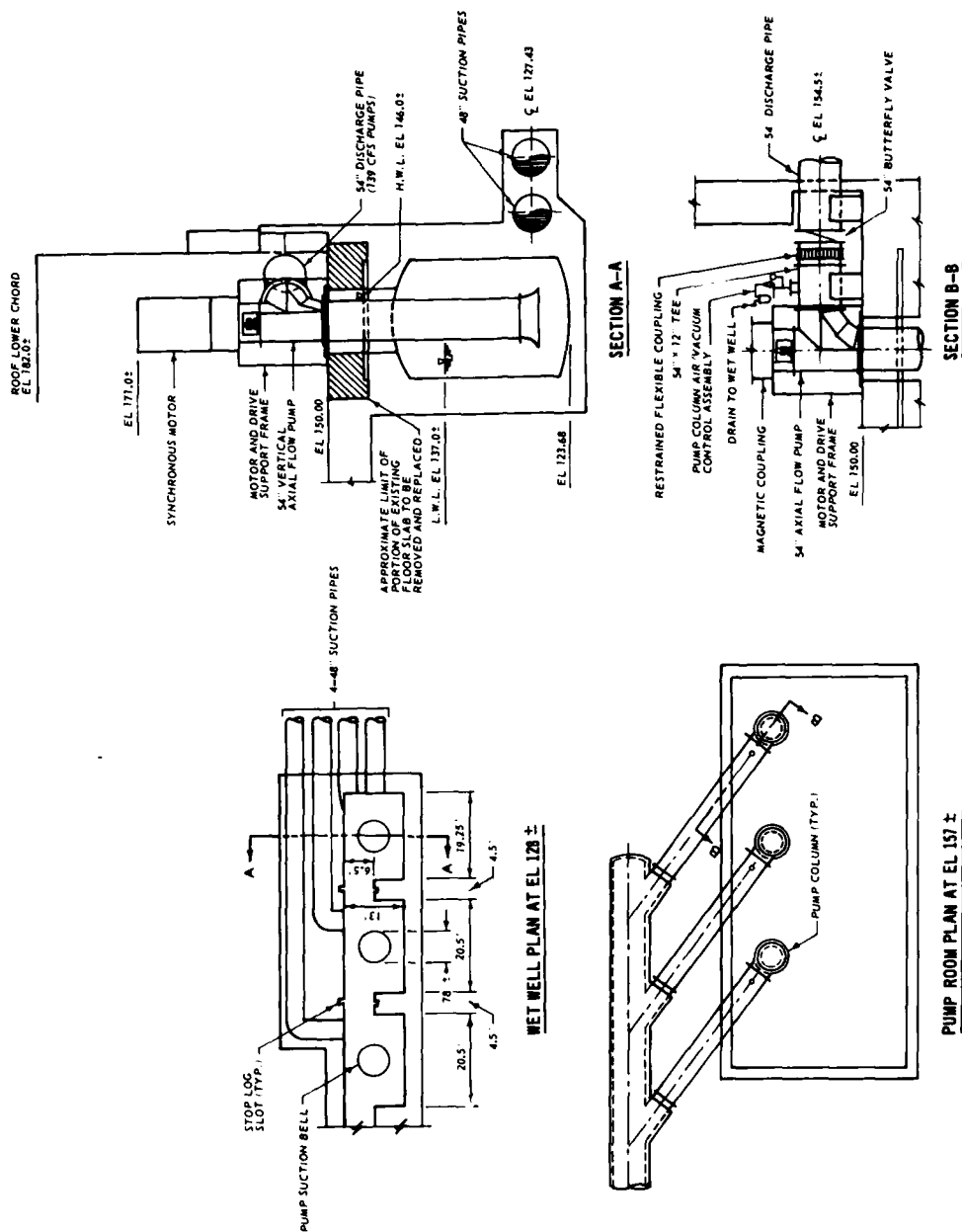


Figure 4. Plans and sections

6. System-head curves were developed (Plates 3 and 4) for the proposed pumps in accordance with the design procedures and constraints. Two pumps of the proposed design and capacity would satisfy the design maximum flow requirement of 125,000 gpm for the water treatment plant and leave one pump available for standby service. Each of the three 54-in. discharge pipes will supply a proposed 84-in. settled water main (Figure 4). This is a factor influencing the system head curve when more than one pump is operating. Model testing was conducted to investigate sump performance for the range of anticipated flow conditions.

7. The net positive suction head (NPSH) is a statement of the minimum suction conditions required to prevent cavitation in a pump. The required or minimum NPSH is usually determined during testing by the manufacturer. The available NPSH should be equal to or greater than the required NPSH if cavitation is to be avoided; increasing the available NPSH provides a margin of safety to help prevent cavitation. The NPSH required for the proposed pumps is shown in Figure 5.

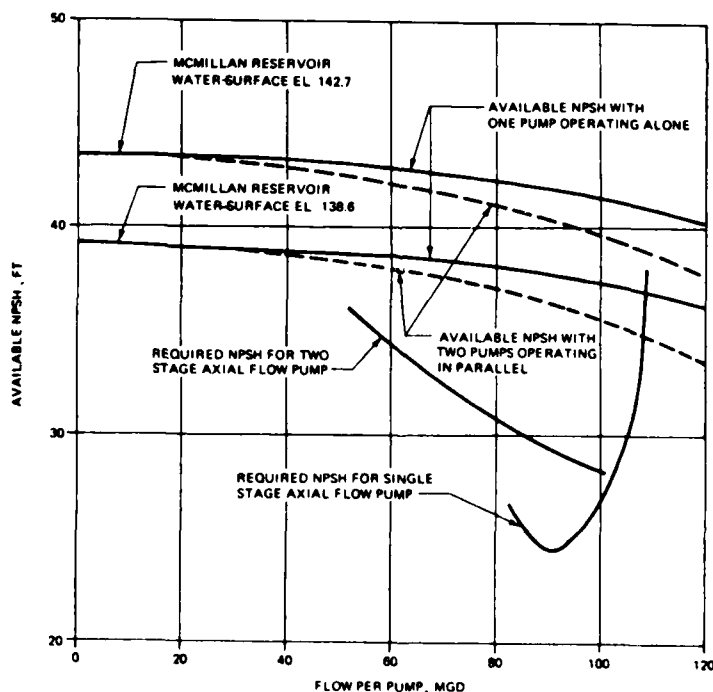


Figure 5. NPSH required for operation of proposed vertical axial flow pumps

Purpose of Model Study

8. The model study was made to evaluate the characteristics of flow into the existing sump that would result with increased discharge capacity due to installation of three new pumps and to develop modifications, if required, within the confines of the existing sump to improve flow distribution to the pump intakes.

PART II: THE MODEL

Description

9. The model of the McMillan Pumping Station was constructed to a scale ratio of 1:9.6. The pump sump was fabricated of transparent plastic to allow photographs and observation of submerged flow conditions (Figure 6). Transparent tape scales were attached to the front of the sump to show both water depth and prototype elevation. A drawing of the model is shown in Plate 5. Approach flow to the sump was simulated by reproducing an appropriate length of inflow piping. A shutoff valve in each of the inflow lines simulated the isolation sluice gates located at the pipe inlets inside the prototype channel. A headbox in the model simulated the prototype channel and received water from each of the three pumps. The water was baffled as it entered the headbox, then it was allowed to flow back into the sump through the four 48-in. (prototype) inflow pipes (simulated). Flow through each of the pump intakes was provided by centrifugal suction pumps located on the floor at the end of the model.

10. An instrument and control console panel was conveniently located beside the sump so that the model operator could monitor the data while also recording visual observations of flow conditions. Special lighting was located beneath each pump intake and directly behind the overall sump to improve visibility of flow conditions. Also, a light was installed above each pump column to indicate when the pump was in operation.

11. Adverse flow conditions were measured in the model by use of vortimeters and pressure transducers. The pressure transducers were mounted flush with the floor of the sump directly beneath the center of each pump intake (Figure 7). The vortimeter is a free-wheeling propeller with four zero-pitched blades (Figure 8). It was located in the pump bell intake at the approximate height or position of the prototype pump propeller. Higher revolutions of the vortimeter indicate more adverse swirl and rotational flow conditions. Submerged vortices, turbulence,



a. Floor level view



b. Elevated view

Figure 6. General view of model

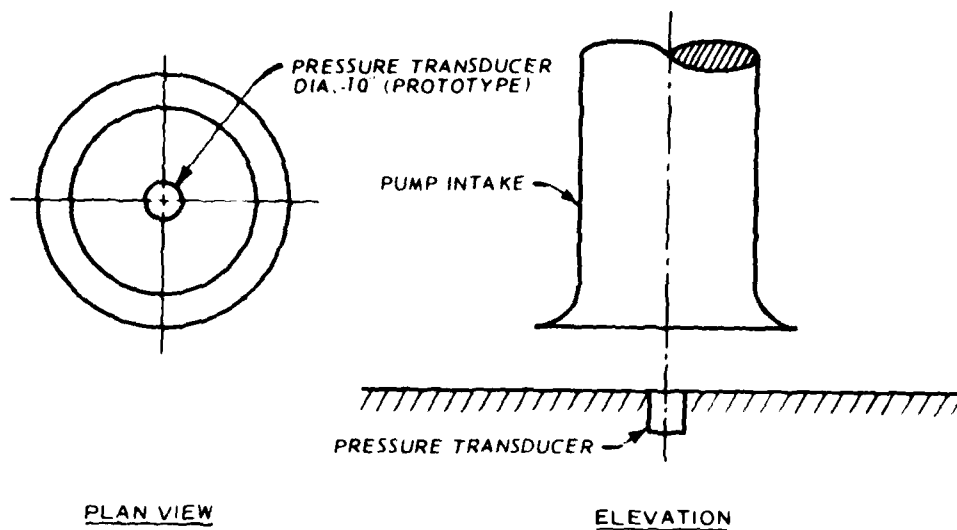


Figure 7. Pressure transducer location

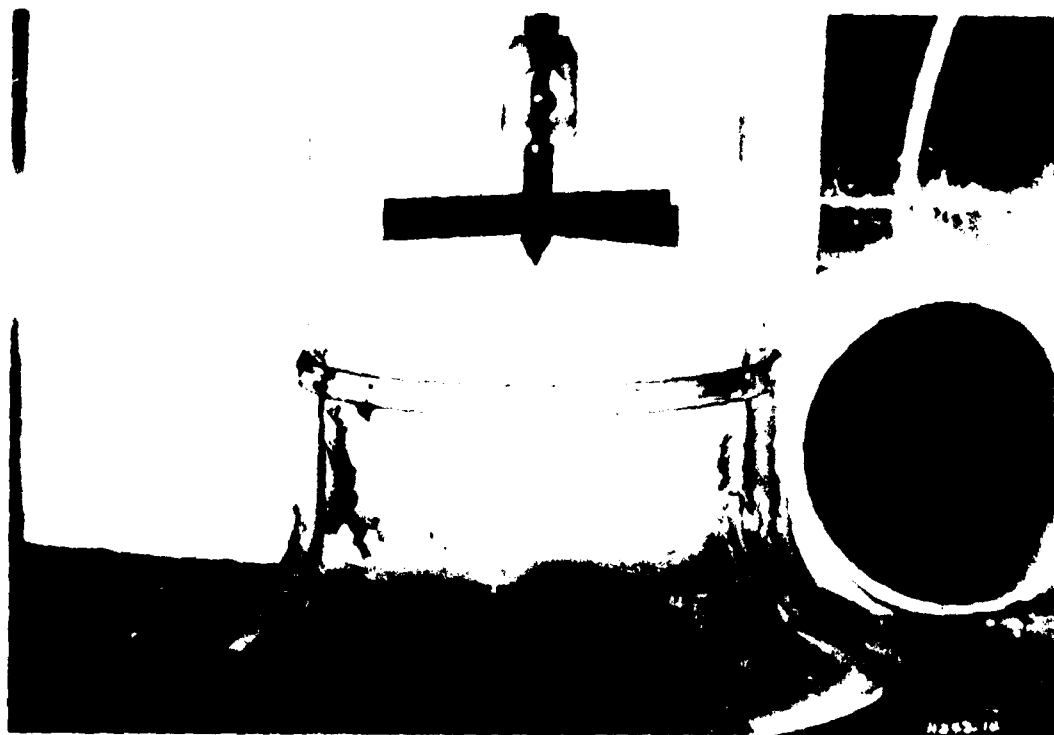


Figure 8. Vortimeter location

and other adverse flow conditions generally cause an increase in pressure fluctuation beneath the pump intake. Turbine flow meters were installed in each of the three pump discharge pipes to measure the discharge. Digital values of the discharge, vortimeter rotation rate, and pressure were displayed on the instrument and control console. Piezometers were installed in each of the four inflow pipes near the sump entrance to measure the degree of flow resistance resulting from the use of the various experimental baffles.

Interpretation of Model Results

12. Accepted equations of hydraulic similitude, based on Froudian criteria, were used to express the mathematical relations between the dimensions and hydraulic quantities of the model and prototype. The general relations expressed in terms of the model scale or length ratio are as follows:

<u>Dimension</u>	<u>Ratio</u>	<u>Scale Relation</u>
Length	$L_r = L$	1:9.6
Area	$A_r = L^2$	1:92.2
Pressure	$P_r = L$	1:9.6
Discharge	$Q_r = L^{5/2}$	1:285.5
Time	$T_r = L^{1/2}$	1:3.1
Frequency	$f_r = \frac{1}{L^{1/2}}$	1:0.323

Values for discharge, water-surface elevation, dimensions, frequency, etc., can be converted quantitatively from the model value to the prototype equivalent by use of these scale factors.

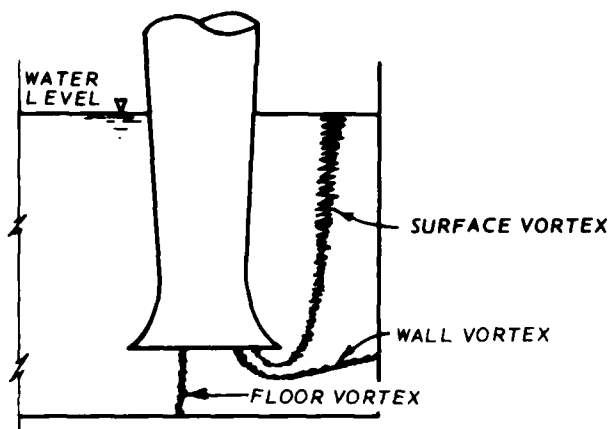
PART III: TESTS AND RESULTS

Original Design

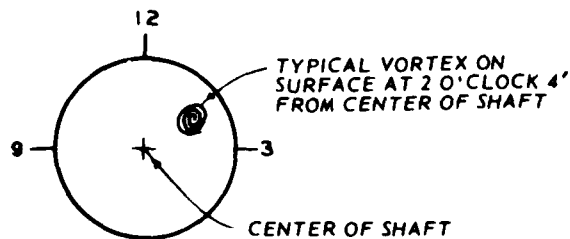
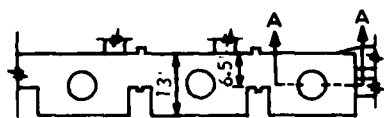
13. The three proposed 54-in. pumps will have a total discharge capacity of 187,500 gpm. The using agency has stated that the rates will vary between 41,600 and 104,200 gpm about 90 percent of the time. This would indicate that no more than two pumps (125,000 gpm) will be used simultaneously except about 10 percent of the time. Model tests were conducted using all possible combinations of the three pumps as well as each pump operating alone. Each possible combination was also operated at three different sump water-surface elevations--139, 143, and 146 ft (the minimum, medium, and maximum sump water levels expected in the prototype). Flow conditions with pump 3 operating for each of the three sump water-surface elevations are shown in Photos 1-3. The pumps are numbered from right to left (see numbers at top of photographs). Dye has been inserted in each case to show the rapid dispersion of flow. The lights near the top of the pump column indicate which pumps are operating. Vortimeter rotation rates and pressure fluctuations are shown in Tables 1 and 2, along with notes about visual observations of flow conditions with each of the pump operating combinations. Various stages of air-entrained vortices and other smaller vortices were observed during these tests. An air-entrained surface vortex can clearly be seen in Photo 4 where dye was inserted to contrast its outline. The phases of vortices, terms used for definition, and abbreviations are shown in Figure 9. Vortimeter rotations were as high as 48 rpm and pressure changes as much as 11.6 ft (prototype). Test results obtained with the original design indicated adverse flow conditions for all anticipated water-surface elevations and combinations of pumps operating.

Experimental Designs

14. Model testing of the original design sump indicated that the primary causes of the adverse hydraulic conditions were the uneven



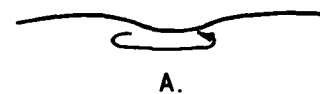
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VORTEX FORMATIONS



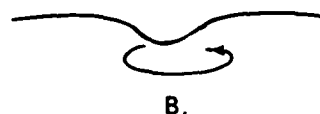
VORTEX ORIENTATION
AS INDICATED BY CLOCK

LIST OF ABBREVIATIONS USED

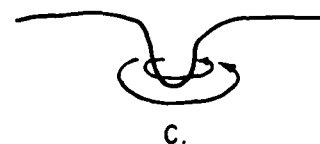
ISV - INTERMITTENT SURFACE VORTEX
SSV - SUSTAINED SURFACE VORTEX
IFV - INTERMITTENT FLOOR VORTEX
SFV - SUSTAINED FLOOR VORTEX
IWV - INTERMITTENT WALL VORTEX
SWV - SUSTAINED WALL VORTEX
IBWV - INTERMITTENT BACK WALL VORTEX
SBWV - SUSTAINED BACK WALL VORTEX
IRSWV - INTERMITTENT
ILSWV - SUSTAINED
CW - CLOCKWISE
CCW - COUNTERCLOCKWISE
CW/CCW - CHANGING CW TO CCW



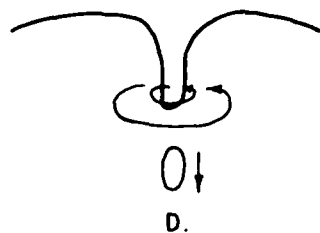
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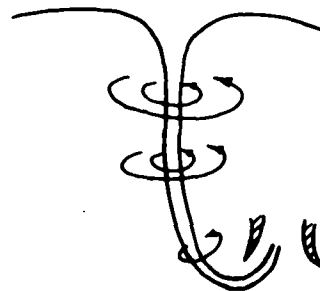
B.



C.



D.



E.
STAGES OF
VORTEX DEVELOPMENT

Figure 9. Vortex formations, definitions, and abbreviations

velocity distribution in the sump approaching the suction bells and the asymmetrical flow entering the bell intakes. The concentrated primary inflow from each of the four 48-in. inflow pipes was 2 to 5 ft away from and normal to the pump intakes. One inflow pipe entered each of the three sump areas except sump area 1, which had two inflow pipes (Plate 5). This caused a secondary rotational crossflow from sump 1 to 2 to 3. Types of alternatives were tested in an attempt to improve the sump design as follows:

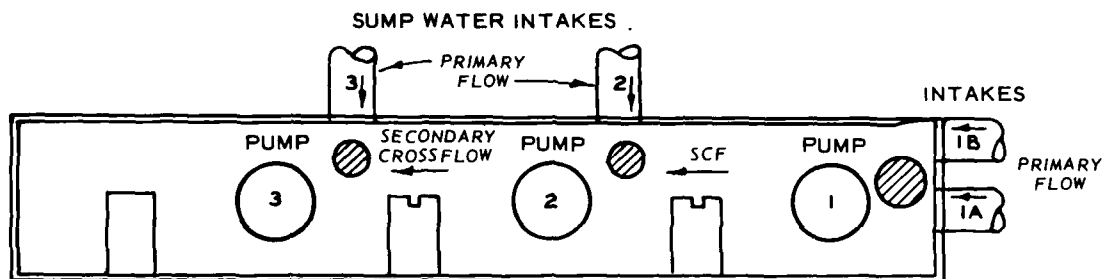
- a. Controlled the flow distribution of the water entering the sump through the four 48-in. pipes.
- b. Varied the pump suction bell distance from the sump floor.
- c. Installed baffles, varying the location, size, and shape of the baffles.

15. A definite improvement was obtained in the flow distribution at the suction bells by adjusting the flow rate of the water entering the sump through the 48-in. inflow pipes. This capability is available at the sluice gates in the prototype channel in lieu of the shutoff valves in the pipes (Plate 5). This experimental method was subsequently abandoned because it was found that each combination of pumps operating required different adjustments of the sluice gate openings.

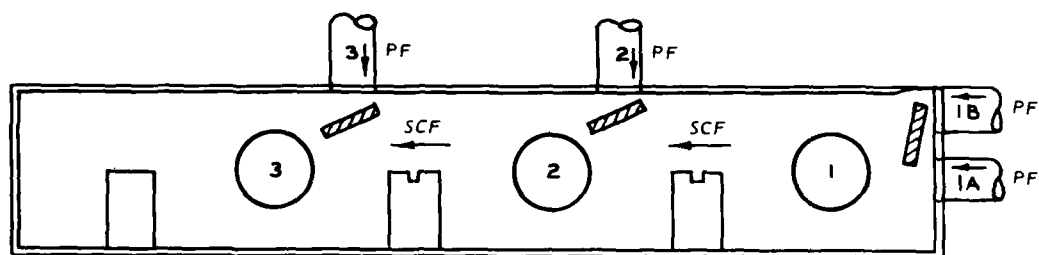
16. During this research study, various bell elevations were investigated, and it was determined that the bell location did have a significant effect on flow conditions at the bell intake; however, this change alone would not provide satisfactory hydraulic performance. As will be discussed later (paragraph 19), the bell height along with the appropriate baffle resulted in the final recommended design.

17. Baffles were tested to investigate their effectiveness for providing uniform flow to the pump intakes.

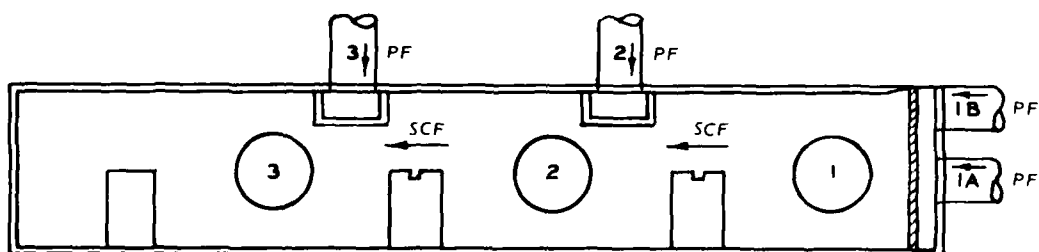
- a. The cylindrical baffles (Figure 10a) were positioned vertically in the sump between the inflow pipes and the pump intakes. Various locations were tried in an effort to balance the flow to the pump intake. Definite improvements were accomplished for any one combination of pumps operating. It was found, however, that the locations of the baffles had to be changed each time the pumps were operated in a different combination. Changes in flow



TYPE 1 CYLINDRICAL BAFFLES



TYPE 2 RECTANGULAR BAFFLES



TYPE 3 STILLING WELL BAFFLES

Figure 10. Experimental baffle types

conditions at the pump intakes were much too sensitive to a slight change in the location of the cylindrical baffles, as well as the changes in the various pump operating combinations.

- b. The rectangular baffles (Figure 10b) were also positioned between the inflow pipes and the pump intakes in an effort to symmetrically distribute the flow to the pump intakes. Results were much the same as those given above for the cylindrical baffles.
- c. The stilling well baffle type (Figure 10c) proved to be the most effective modification for improving hydraulic flow in the sump. This type of baffle dissipates some of the excessive kinetic energy of the inflow and improves the flow distribution to the pump intakes. Numerous baffle sizes and locations were investigated to determine the most satisfactory design for all anticipated flow conditions. In the original design, vortimeter rotation was clockwise (cw) in pump columns 2 and 3. This was the result of the concentrated primary flow through the 48-in. pipes overriding the secondary crossflow (scf) through the log gate passageways (Figure 10). Experiments showed that stilling well baffles with top elevations greater than el 128.2 and el 126.0 for pumps 2 and 3, respectively, would cause vortimeter rotation to change to counterclockwise (ccw). This meant that more of the primary flow from the 48-in. pipes was not going in the same general direction as the crossflow through the log gate passageways. More even flow distribution was obtained when these forces were nearly equalized.

18. In section 1 of the original sump design (Plate 5), the vortimeter rotation was ccw because one of the 48-in. pipes entered at the side of the sump while the other entered near the center. The best flow condition in this section was obtained with the top of the stilling well baffle at el 128.2 and the bottom of the bell at el 126.2.

Recommended Design

19. Stilling well baffles in proper size and location along with the proper bell elevation or distance or above the sump floor provided satisfactory hydraulic performance for all anticipated water-surface elevations and combinations of pumps operating. The baffles diverted the flow upward and away from the proximity of the pump intakes.

Determination of the optimum location, height, and width of the baffles by means of the model also provided more uniform flow distribution between the primary inflow and the secondary crossflow (Figure 10). Determination of the best pump bell elevation also improved flow conditions at the individual pump intakes. Flow conditions with the recommended design for maximum and minimum sump water-surface elevations are shown in Photos 5-7. Dye was inserted to provide a clearer indication of rapid flow dispersion. The baffles were painted black. Size, configuration, and location of the baffles and pump bell elevation are shown in Plate 6.

20. Dimples in the sump water surface and occasional surface vortices were observed with the recommended design; however, these conditions should not affect performance of the prototype pumps. In the event they do, a vortex suppressor which was tested in the model would eliminate this condition (Plate 6). The vortex suppressor was a baffle (6 ft high \times 7 ft wide) positioned across the sump between pumps 1 and 2. It reduced rotational surface flow conditions. To be effective, the bottom of the vortex suppressor should extend to el 138, approximately 1 ft below the minimum sump water-surface elevation expected, and the top should be at el 144, or 2 ft below the maximum sump water-surface elevation expected. The size and location with respect to water-surface elevation are also shown in Plate 6. Installation of a gate between pumps 1 and 2 lowered to el 138 (bottom edge) is an option for accomplishing the same results as the 7-ft-high by 7-ft-wide vortex suppressor.

21. Vortices were eliminated with the recommended design (paragraph 19, Plate 6); swirl and pressure fluctuations were reduced substantially. Values for pressure and swirl along with pertinent comments are shown in Table 2. Comparison of swirl conditions (vortimeter rotation rates) observed in the original and the recommended sump designs are shown in Figure 11. Pressure fluctuations were reduced from an average of approximately 7 ft of water with the original design to near zero with the recommended design. Comparisons of pressure variations measured in the original and the recommended sump designs are shown in Figure 12. Swirl and pressure fluctuation comparisons shown in Figures 11 and 12 were determined for the minimum (el 139), medium (el 143),

and maximum (el 146) sump water-surface elevations expected in the prototype. Values for pressure and swirl along with pertinent comments are shown in Table 2. Results obtained with the recommended design were satisfactory for all anticipated water-surface elevations and combinations of pumps operating.

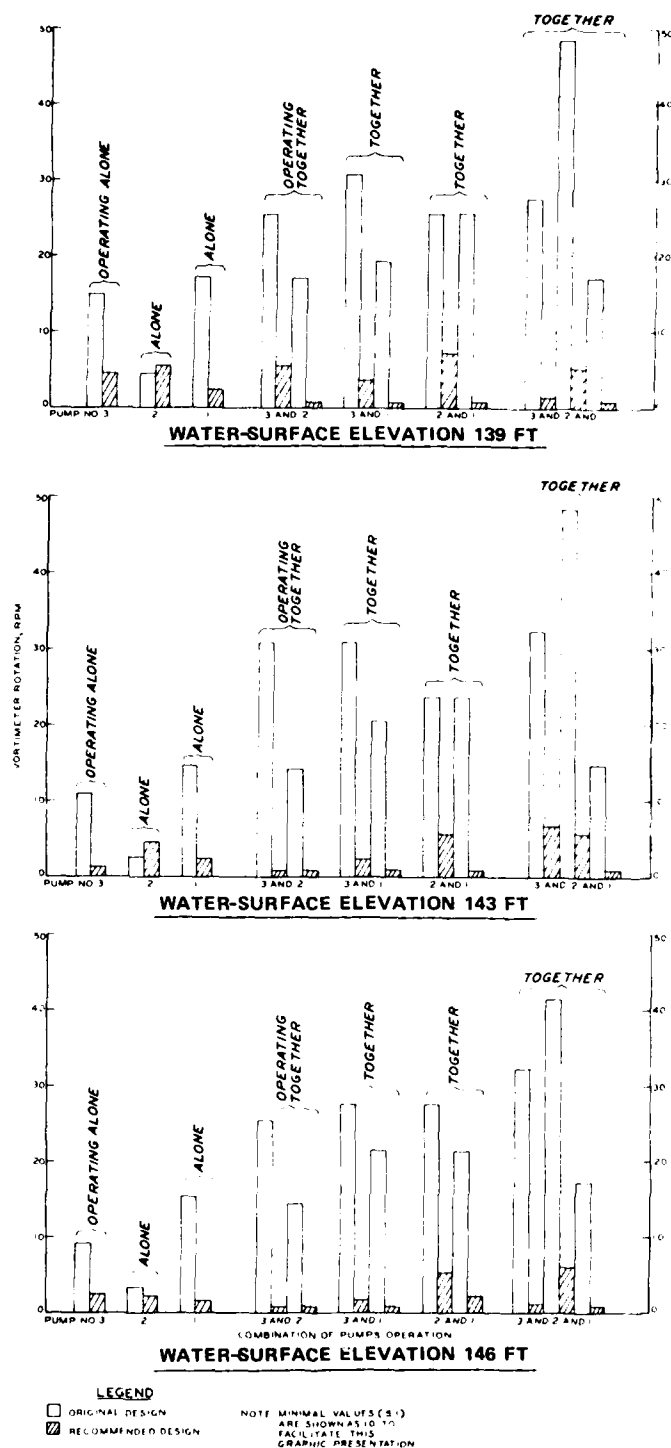


Figure 11. Sump characteristics; swirl versus combinations of pumps operating. Discharge per pump 62,500 gpm; water-surface elevations 139, 143, and 146

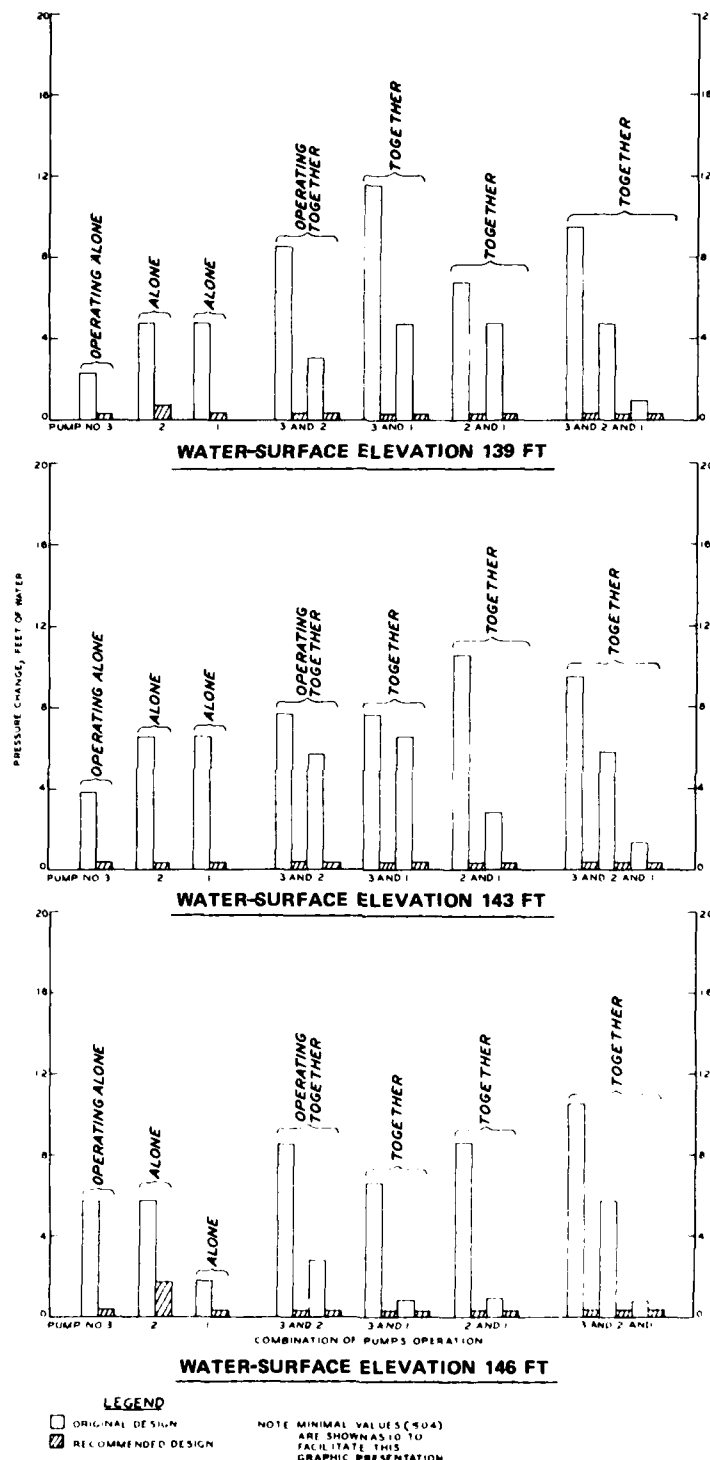


Figure 12. Sump characteristics; pressure change versus combinations of pumps operating. Discharge per pump 62,500 gpm; water-surface elevations 139, 143, and 146

PART IV: CONCLUSIONS

22. Hydraulic performance of the pump sump was improved to a satisfactory level for all anticipated water-surface elevations and combinations of pumps operating by means of stilling well baffles and a proper bell elevation developed during the model study. The stilling well baffles caused a substantial reduction in the severe flow instability, swirl, and pressure fluctuations observed in the vicinity of the original design sump pump intakes.

23. The major hydraulic problems discovered by the model tests were caused by the concentrated inflows from a direction normal to the bell intakes. In sump area 1, this problem was magnified due to the two inflow pipes supplying that area as compared with only one pipe supplying each of the other two sump areas. In sump areas 2 and 3, the primary inflow from a direction normal to the pump intakes was further complicated by the secondary crossflow contributed from sump area 1 due to its additional inflow pipe.

24. The stilling well baffles developed during model tests diverted the primary inflow upward away from the pump intakes, dissipated some of the excessive kinetic energy of the concentrated inflow, and essentially eliminated the adverse rotational effect of the secondary crossflow. Adjustment of the size and shape of the stilling well baffles along with the elevation of the pump bell was the effective means used to obtain a more balanced velocity distribution and symmetrical flow into the pumps.

25. With the improved flow conditions, vortices were eliminated and swirl and pressure fluctuations were reduced substantially. Vortimeter rotation rates were reduced from an average of approximately 25 rpm with the original design to an average of about 4 rpm with the recommended design.

Table 1
Original Design Sump, Scale 1:9.6

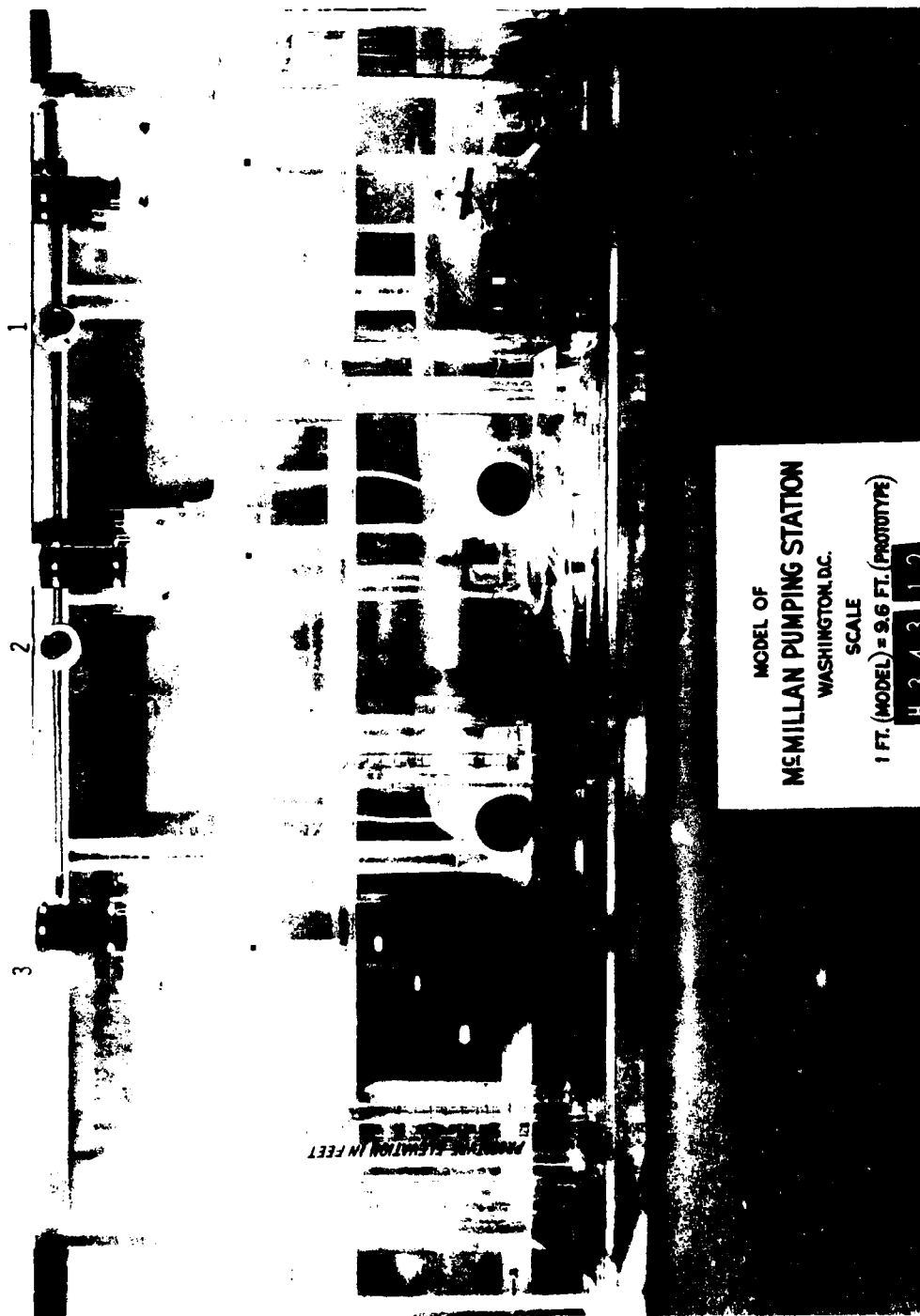
Run No.	Model Water Level ft.	Prototype Water-Surface Elev., ft.	Discharge gpm			Vortimeter Reading rpm			Number of Pumps Operating	Pressure Cell Reading (feet of water)					
			Pump 3	Pump 2	Pump 1	Pump 3	Pump 2	Pump 1		Pump 3		Pump 2		Pump 1	
										Min	Max	Min	Max	Min	Max
1	1.6	139	62,500	X	X	16.1+	X	X	1	13.4	15.4	X	X	X	X
		ISV at 9 o'clock, ISV at 3 o'clock, both stage D and CCW													
2	1.6	139	X	62,500	X	X	4.8+	X	1	X	X	10.6	15.4	X	X
		Sump 2 has ISV's at 2-5 o'clock, all stage B and CCW													
3	1.6	139	X	X	62,500	X	X	17.1+	1	X	X	X	X	10.6	15.4
		Two ISV's at 3 and 5 o'clock, both stage A and CCW													
4	1.6	139	62,500	62,500	X	25.8+	17.1+	X	2	5.8	14.4	11.5	15.4	X	X
		Sump 3 has ISV at 7 o'clock, stage A, also same at 5 o'clock, sump 2 ISV's at 7 and 2 o'clock CCW Sump 1 ISV at 1 o'clock CCW													
5	1.6	139	62,500	X	62,500	31.0+	X	19.4+	2	3.8	15.4	X	X	10.6	15.4
		Sump 3 ISV's at 8-9 o'clock CW/CCW, same at 1-2 o'clock, sump 1 ISV at 7-10 o'clock CW, all stage B													
6	1.6	139	X	62,500	62,500	X	25.8+	25.8+	2	X	X	8.6	15.4	10.6	15.4
		Sump 2 ISV's at 1, 5, and 10 o'clock, CW/CCW, sump 1, ISV's at 4, 7, and 8 o'clock, CW/CCW, all stage B													
7	2.3	143	62,500	X	X	11.0+	X	X	1	16.3	20.2	X	X	X	X
		ISV's CCW stage A, circulating all around sump 3, no vortices in sumps 2 and 1													
8	2.0	143	X	62,500	X	X	2.9+	X	1	X	X	12.5	19.2	X	X
		Almost no surface motion													
9	2.0	143	X	X	62,500	X	X	14.8+	1	X	X	X	X	12.5	19.2
		Surface relatively still													
10	2.0	143	62,500	62,500	X	31.0+	14.2+	X	2	9.6	17.3	13.4	19.2	X	X
		Surface relatively still													
11	2.0	143	62,500	X	62,500	31.0+	X	20.7+	2	9.6	17.3	X	X	12.5	19.2
		Surface relatively still													
12	2.0	143	X	62,500	62,500	X	23.9+	23.9+	2	X	X	8.6	19.2	16.3	19.2
		Surface relatively still													
13	2.3	146	62,500	X	X	8.1+	X	X	1	16.3	22.1	X	X	X	X
		ISV, stage B, CCW at 3 o'clock													
14	2.3	146	X	62,500	X	X	3.4+	X	1	X	X	16.3	22.1	X	X
		Water relatively calm													
15	2.3	146	X	X	62,500	X	X	15.5+	1	X	X	X	X	20.2	22.1
		Water relatively calm, no significant vortices													
16	2.3	146	62,500	62,500	X	25.8+	14.8+	X	2	12.5	21.1	19.2	22.1	X	X
		Very tiny vortices in sumps 3 and 2, mostly in sump 3													
17	2.3	146	62,500	X	62,500	27.8+	X	21.6+	2	12.5	19.2	X	X	21.1	22.1
		Water relatively calm													
18	2.3	146	X	62,500	62,500	X	27.8+	22.6+	2	X	X	13.4	22.1	21.1	22.1
		Water relatively calm													
19	2.0	143	62,500	62,500	62,500	23.3+	48.4+	14.8+	3	8.6	18.2	13.4	19.2	18.2	19.2
		Considerable turbulence and swirl but only tiny vortices													
20	1.6	139	62,500	62,500	62,500	27.8+	48.4+	19.4+	3	5.8	15.4	10.6	15.4	14.4	15.4
		Considerable turbulence and swirl but only tiny vortices													
21	2.3	146	62,500	62,500	62,500	32.7+	41.6+	17.1+	3	11.5	21.1	16.3	22.1	19.2	21.1
		Considerable turbulence and swirl but only tiny vortices													

NOTE: Runs 1-21 were made with all inflow valves open, all sump gates removed, and the pump bells located 3 in. (2.4 ft prototype) off the sump floor.
See Figure 9 for definition of symbols, terms, and abbreviations.
An "X" is used in pertinent data columns to show data irrelevant due to a specific pump not operating.

Table 2
Recommended Design Sump, Scale 1:9.6

Run No.	Model Water Level ft.	Prototype Water-Surface El., ft.	Discharge			Vortimeter Reading			Number of Pumps Operating	Pressure Cell Reading (feet of water)						Remarks		
			gpm	Pump 3	Pump 2	Pump 1	rpm	Pump 3		Pump 2	Pump 1	Pump 3		Pump 2			Pump 1	
												Min.	Max.	Min.	Max.		Min.	Max.
1	1.6	139	62,500	X	X	4.8+	X	X	1	14.4	14.9	X	X	X	X	No vortices		
2	1.6	139	X	62,500	X	X	5.5+	X	1	X	X	14.1	14.9	X	X			
		Several ISV's stage A CCW moving from 2 to 12 to 1 o'clock																
3	1.6	139	X	X	62,500	X	X	2.3+	1	X	X	X	X	14.9	15.7			
		ISV at 7 o'clock, stage D, CW																
4	1.6	139	62,500	62,500	X	5.8+	0	X	2	14.7	14.9	14.5	14.9	X	X	No vortices		
5	1.6	139	62,500	X	62,500	3.9+	X	1.0+	2	14.6	14.9	X	X	14.9	15.1	No vortices		
6	1.6	139	X	62,500	62,500	X	7.1+	0.3+	2	X	X	14.7	14.9	14.9	15.1	No vortices		
7	2.0	143	62,500	X	X	1.3+	X	X	1	18.9	19.3	X	X	X	X			
		ISV stage A at 7 o'clock CCW																
8	2.0	143	X	62,500	X	X	4.5+	X	1	X	X	18.9	19.1	X	X	No vortices		
9	2.0	143	X	X	62,500	X	X	2.6+	1	X	X	X	X	19.1	19.3	No vortices		
10	2.0	143	62,500	62,500	X	1.0+	0	X	2	18.9	19.2	18.8	19.1	X	X	No vortices		
11	2.0	143	62,500	X	62,500	2.3+	X	1.0+	2	19.0	19.2	X	X	19.0	19.1	No vortices		
12	2.0	143	X	62,500	62,500	X	5.5+	0.3+	2	X	X	18.9	19.0	18.9	19.1	No vortices		
13	2.3	146	62,500	X	X	2.3+	X	X	1	21.6	22.1	X	X	X	X	No vortices		
14	2.3	146	X	62,500	X	X	2.3+	X	1	X	X	20.3	22.1	X	X	No vortices		
15	2.3	146	X	X	62,500	X	X	1.9+	1	X	X	X	X	21.5	21.7			
		ISV stage A at 7 o'clock CW																
16	2.3	146	62,500	62,500	X	0.3+	0	X	2	21.8	22.0	21.7	21.9	X	X	No vortices		
17	2.3	146	62,500	X	62,500	1.9+	X	0	2	21.9	22.1	X	X	21.8	22.0	No vortices		
18	2.3	146	X	62,500	62,500	X	5.5+	2.3+	2	X	X	21.7	21.9	21.6	21.9	No vortices		
19	2.0	143	62,500	62,500	62,500	6.8+	5.8+	0	3	18.8	19.1	18.8	19.1	18.8	19.1	No vortices		
20	1.6	139	62,500	62,500	62,500	8.4+	1.8+	1.1+	3	14.6	14.9	14.7	15.0	14.6	15.0	No vortices		
21	2.3	146	62,500	62,500	62,500	1.3+	6.1+	0.6+	3	21.8	22.1	21.7	22.0	21.7	21.9	No vortices		

NOTE: Runs 1-21 were made with all inflow valves open, all sump gates removed, and recommended baffles installed. Sump bell 1 was at el 126.0, pump bells 2 and 3 were at el 125.8.
An "X" is used in certain data columns to show data irrelevant due to a specific pump not operating.
All recorded data are prototype data.
Refer to Figure 2 for a definition of symbols, terms, and definitions.



MODEL OF
MEMILLAN PUMPING STATION

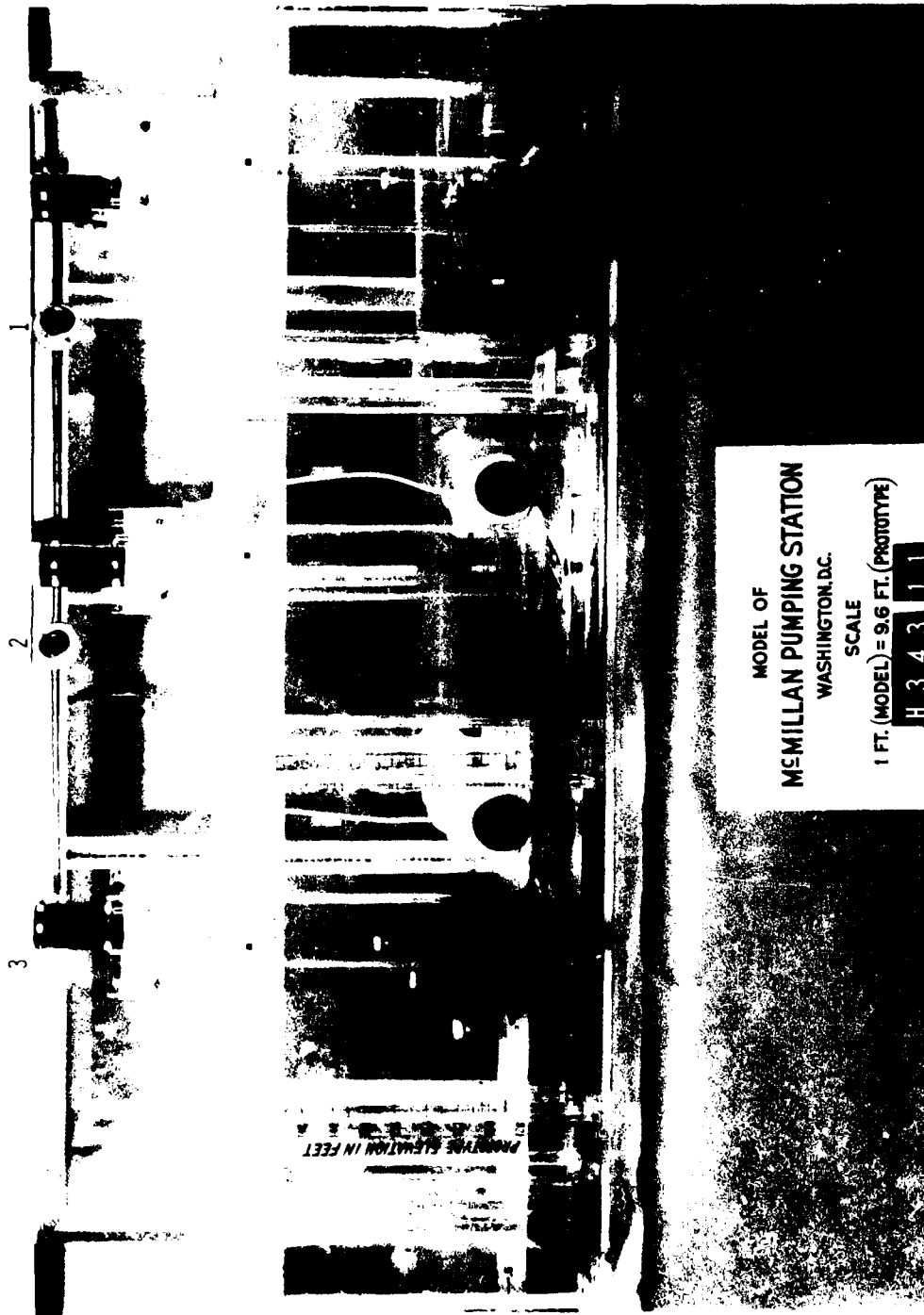
WASHINGTON, D.C.

SCALE

1 FT. (MODEL) = 2.6 FT. (PROTOTYPE)

34312

U.S. GOVERNMENT PRINTING OFFICE: 1964 O 34312



MODEL OF
McMILLAN PUMPING STATION
WASHINGTON, D.C.

SCALE
1 FT. (MODEL) = 9.6 FT. (PROTOTYPE)

1 2 3 4



MODEL OF
McMILLAN PUMPING STATION
 WASHINGTON, D.C.
 SCALE
 1 FT. (MODEL) = 9.6 FT. (PROTOTYPE)
 H 3 4 3 1 0

Photo 3. Original pump section with pump 3 operating (el 146)



MODEL OF
MEMILLAN PUMPING STATION

WASHINGTON, D.C.

SCALE

1 FT. (MODEL) = 9.6 FT. (PROTOTYPE)

343



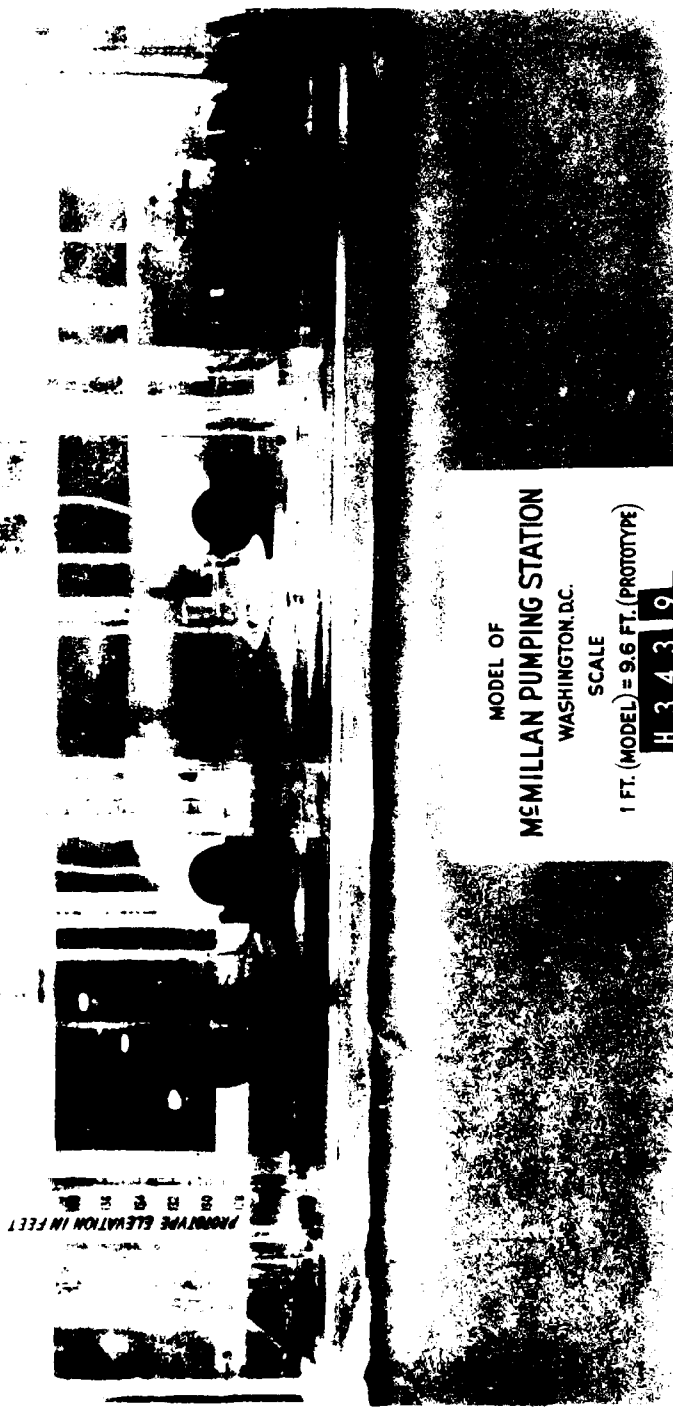
Model of the McMillan Pumping Station, Washington, D.C., showing the structure and the scale of the model.



MODEL OF
McMILLAN PUMPING STATION
WASHINGTON, D.C.

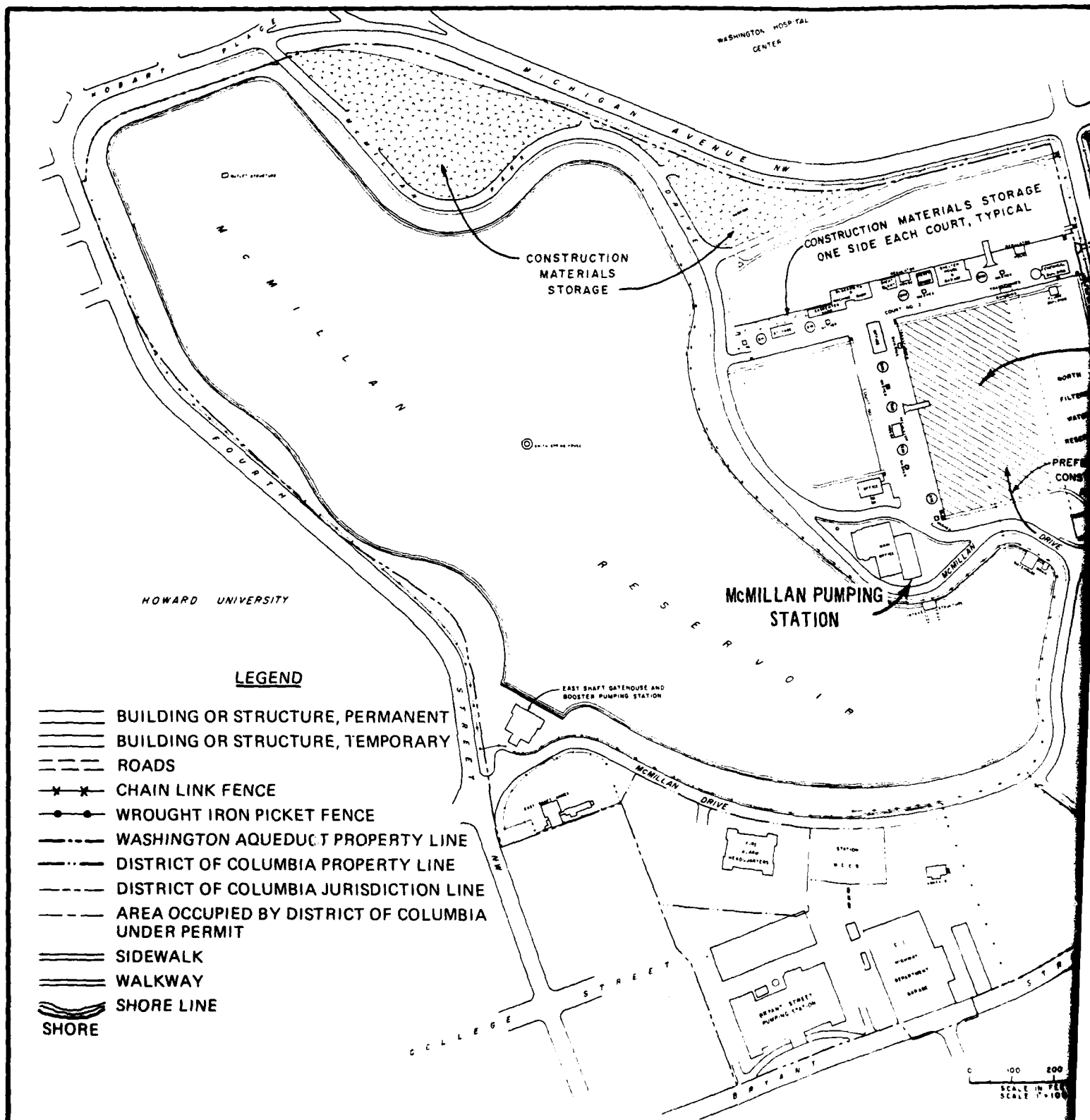
SCALE
1 FT. (MODEL) = 9.6 FT. (PROTOTYPE)

1 2 3 4 5 6 7 8



MODEL OF
MEMILLAN PUMPING STATION
WASHINGTON, D.C.
SCALE
1 FT. (MODEL) = 9.6 FT. (PROTOTYPE)
H 3 4 3 9

See also drawing of pump station with motor in 20 ft. long with no pump operator (60 130)



WASHINGTON HOSPITAL
CENTER

CONSTRUCTION MATERIALS STORAGE
ONE SIDE EACH COURT, TYPICAL

PROPOSED FILTER AND
CHEMICAL BUILDING SITE

McMILLAN PUMPING
STATION

PREFERRED
CONSTRUCTION
ACCESS

NORTH
FILTERED
WATER
RESERVOIR

SOUTH
FILTERED
WATER
RESERVOIR

NOTE:

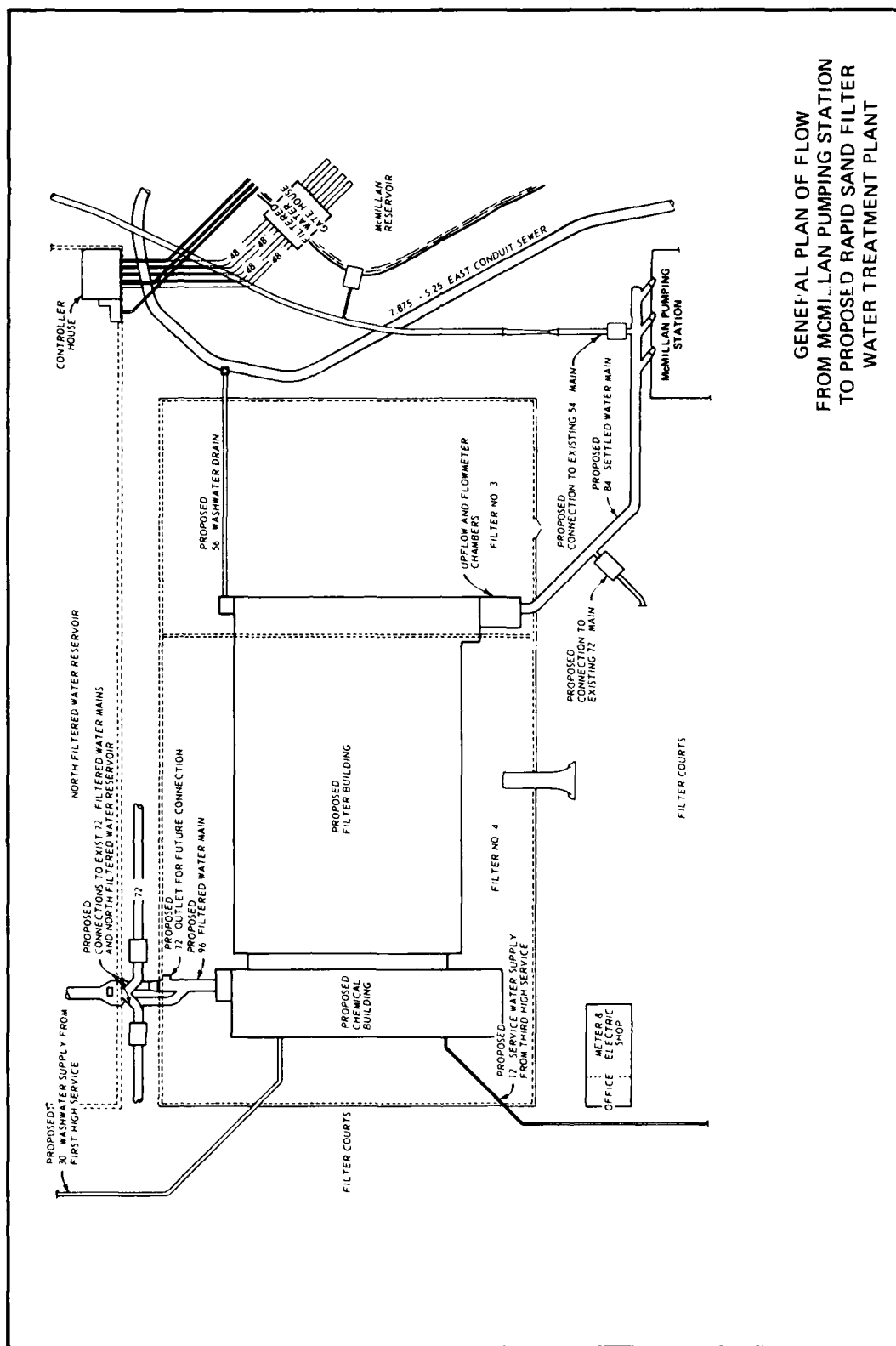
1. BASE MAP DATA TAKEN FROM WASHINGTON
AQUEDUCT DRAWING NO. 70.19-1.1-1,
McMILLAN MASTER PLAN, GENERAL SITE
PLAN.
2. SHADED STRUCTURES LOCATED IN FILTER
COURTS 1 AND 2 ARE TO BE REMOVED.

WASHINGTON AQUEDUCT
McMILLAN WATER TREATMENT PLANT

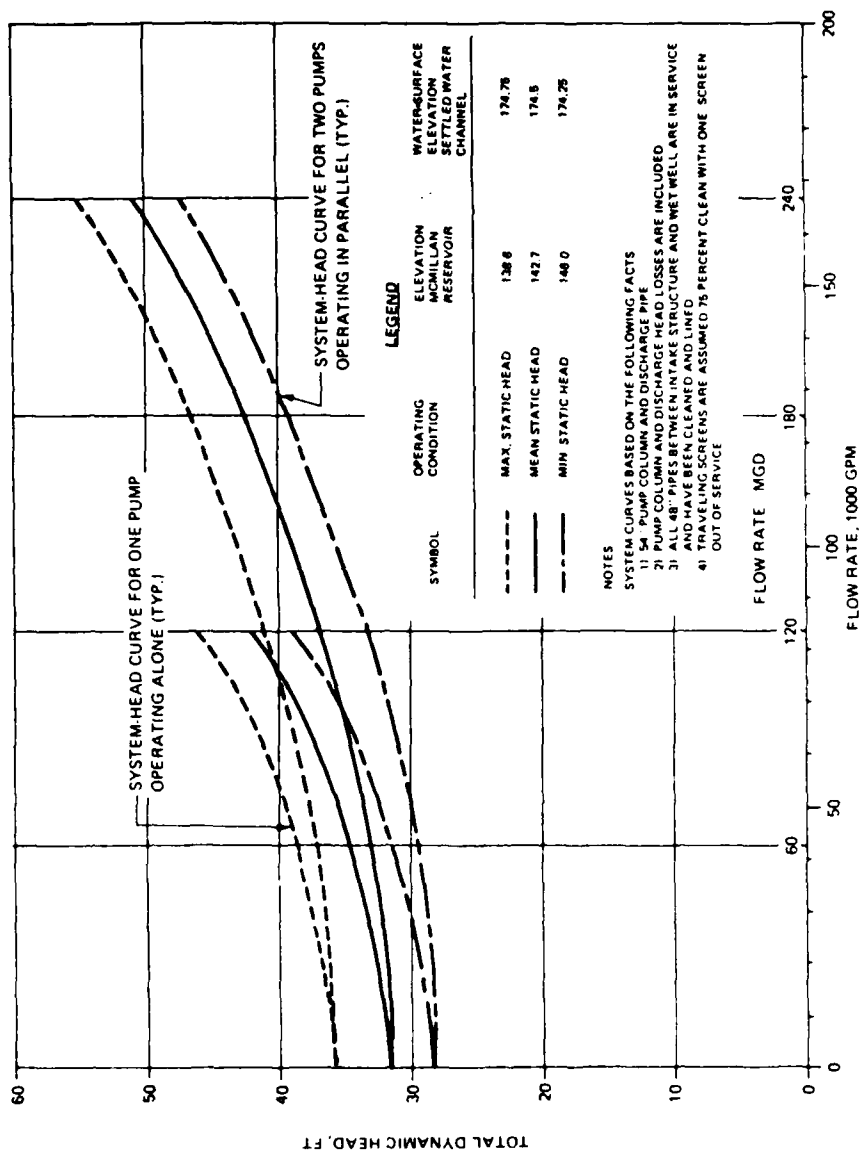
GENERAL PLAN

0 100 200 300
SCALE IN FEET
SCALE 1" = 100'

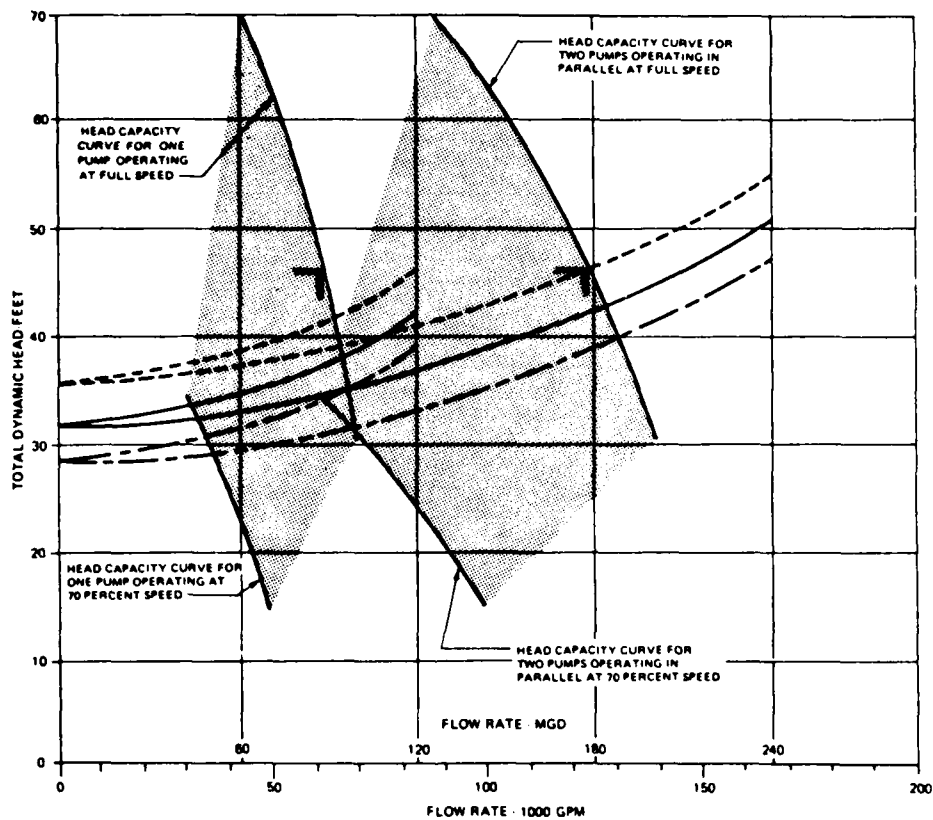
12



GENERAL PLAN OF FLOW
FROM McMILLAN PUMPING STATION
TO PROPOSED RAPID SAND FILTER
WATER TREATMENT PLANT



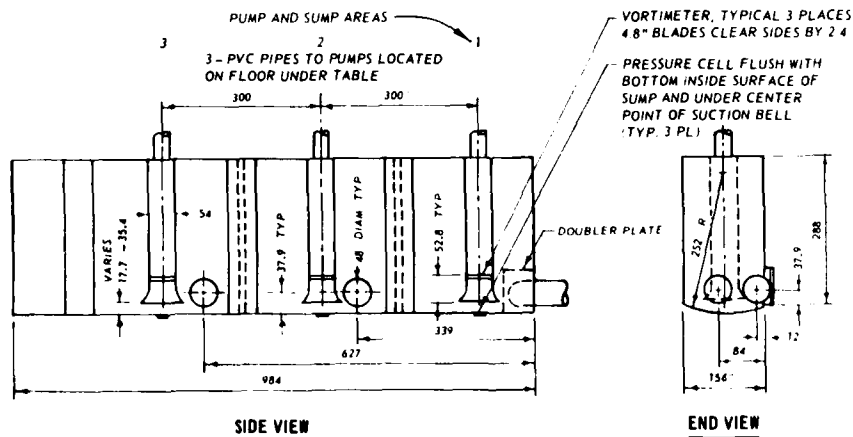
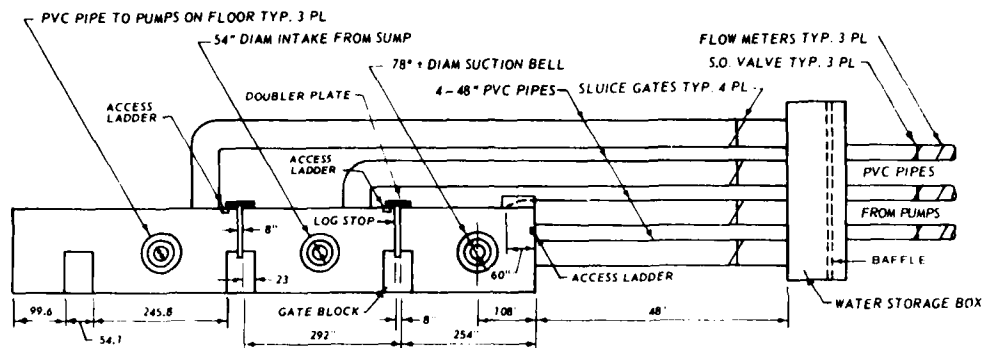
SYSTEM-HEAD CURVES
FOR PROPOSED PUMPS



NOTES:

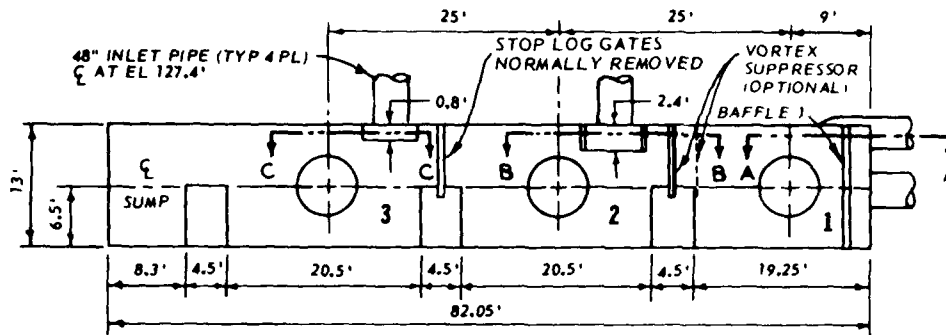
- 1) PLATE 3 PRESENTS BASIS FOR SYSTEM-HEAD CURVES
- 2) PUMP HEAD CAPACITY CURVES ARE BASED ON TWO-STAGE VERTICAL AXIAL FLOW PUMPS
- 3) PUMP BOWL EFFICIENCY FOR ALL PUMPS IS AT LEAST 80 PERCENT WITHIN SHADED AREA
- 4) PUMP HEAD CAPACITY CURVES SHOWN FOR PARALLEL OPERATION OF TWO PUMPS ARE BASED ON BOTH PUMPS OPERATING AT THE SAME SPEED

**HEAD CAPACITY CURVES FOR
PROPOSED VARIABLE SPEED PUMPS**

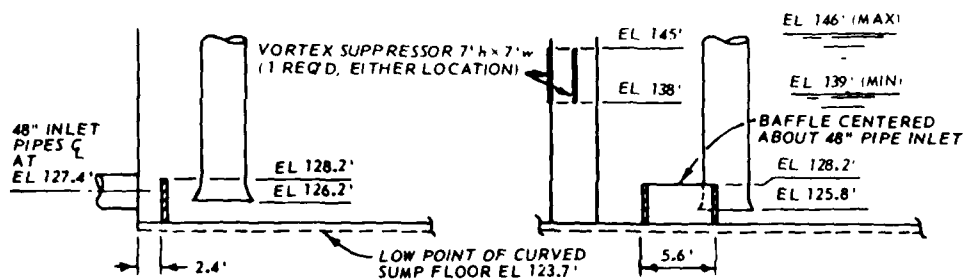


NOTE: ALL DIMENSIONS ARE PROTOTYPE DIMENSIONS.

DETAILS AND LIMITS OF THE MODEL

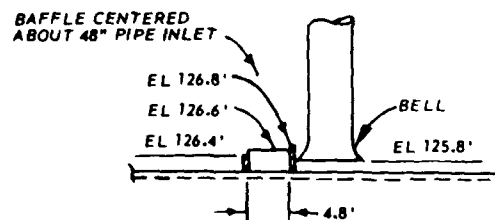


PLAN VIEW WITH BAFFLES



SECTION A-A, BAFFLE 1

SECTION B-B, BAFFLE 2



SECTION C-C, BAFFLE 3

RECOMMENDED DESIGN

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

Triplett, Glenn R

McMillan Pumping Station, Washington, D. C.; hydraulic model investigation / by Glenn R. Triplett. Vicksburg, Miss. : U. S. Waterways Experiment Station; Springfield, Va. : available from National Technical Information Service, 1980.

25, [9] p., [4] leaves of plates: ill. ; 27 cm. (Technical report - U. S. Army Engineer Waterways Experiment Station ; HL-80-19)

Prepared for U. S. Army Engineer District, Baltimore, Baltimore, Maryland.

1. Baffles. 2. Flow distribution. 3. Hydraulic models. 4. McMillan Pumping Station. 5. Pump intakes. 6. Pumping stations. 7. Sumps. I. United States. Army. Corps of Engineers. Baltimore District. II. Series: United States. Waterways Experiment Station, Vicksburg, Miss. Technical report ; HL-80-19.
TA7.W34 no.HL-80-19